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Standard
Test Method

Laboratory Test Procedures for Evaluation of SOHIC Resistance of Plate Steels Used in Wet H_2S Service

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Foreword

Carbon steel plates employed in welded pressure vessels may be susceptible to one or more forms of environmental cracking when exposed to wet H_2S service conditions. These include (1) sulfide stress cracking (SSC) of hard welds and heat-affected zones (HAZ); (2) hydrogen-induced cracking (HIC) in the base metal; and (3) stress-oriented hydrogen-induced cracking (SOHIC), for example, in the region adjacent to weldments of nominally acceptable hardness. (Definitions of these forms of cracking are presented in Paragraph 1.3.) Extensive work has been conducted over many years to understand various fundamental and applied aspects of these phenomena. Due to recent experiences in refinery wet H_2S operations, attention has been particularly directed to understanding SOHIC and the various metallurgical and environmental parameters that govern its occurrence.

Recent technical publications[1-7] and NACE technical committee reports[8, 9] and standards[10] have focused on several issues related to the serviceability of carbon steel equipment in wet H_2S service. One of these issues is the evaluation of steels to determine their resistance to SOHIC. Other test methods have been standardized for evaluation of SSC and HIC; NACE Standards TM0177[11] and TM0284[12] are extensively utilized in the evaluation and qualification of steels for determination of resistance to SSC and HIC, respectively. However, neither of these test methods deals directly with the specific mechanism and mode of cracking inherent to SOHIC.

The following situation illustrates the shortcomings of the existing test methods in the evaluation of SOHIC. Cracking observed in steel equipment resulting from SOHIC appears to be mechanistically related to HIC because it involves the formation of small blisters in the steel (from the recombination of atomic hydrogen to molecular hydrogen) and the development of interconnecting cracks that link adjacent blisters on different planes in the steel. The small blisters characteristic of HIC typically form parallel to the plate surface (see Figure 1). However, in SOHIC, the orientation of these blisters is much different. The presence of an applied or residual tensile stress in the steel (typically adjacent to the weld HAZ) produces stacked arrays of these blisters and the interconnecting cracking is oriented in the through-thickness direction (see Figure 2). NACE Standard TM0284, while being an acceptable test method for evaluation of HIC, lacks the application of tensile stress and therefore cannot provide an evaluation of this through-thickness cracking process involved in SOHIC.

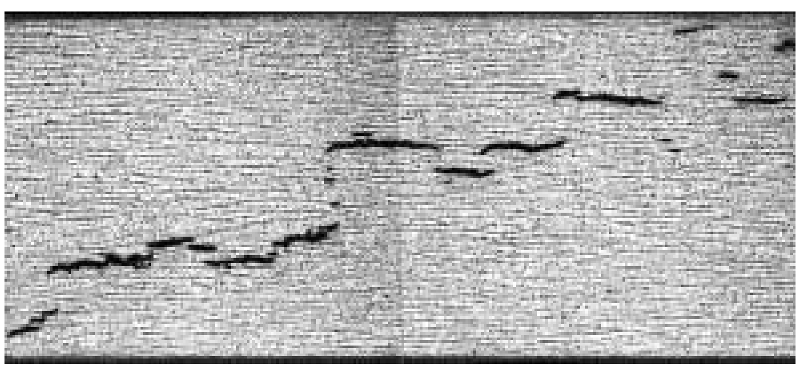

FIGURE 1—HIC in Carbon Steel Under No Applied Stress

The test method defined by NACE Standard TM0177 utilizes stressed specimens and has been effective in evaluating SSC. It is particularly useful for defining threshold stresses below which rupture by SSC does not occur for specific steels and conditions of steels. The TM0177 test method was originally developed and is extensively utilized to evaluate SSC susceptibility in high-strength, low-alloy steels and other materials, which usually occurs without extensive internal cracking. In some cases, blistering is observed. The TM0177 test method has been shown to produce extensive through-thickness arrays of blisters with interconnecting cracks (i.e., SOHIC) in some steels. But, in other cases, test specimens with extensive internal cracking do not rupture. Therefore, differentiation in susceptibility of materials to SOHIC using TM0177 can be somewhat ambiguous.

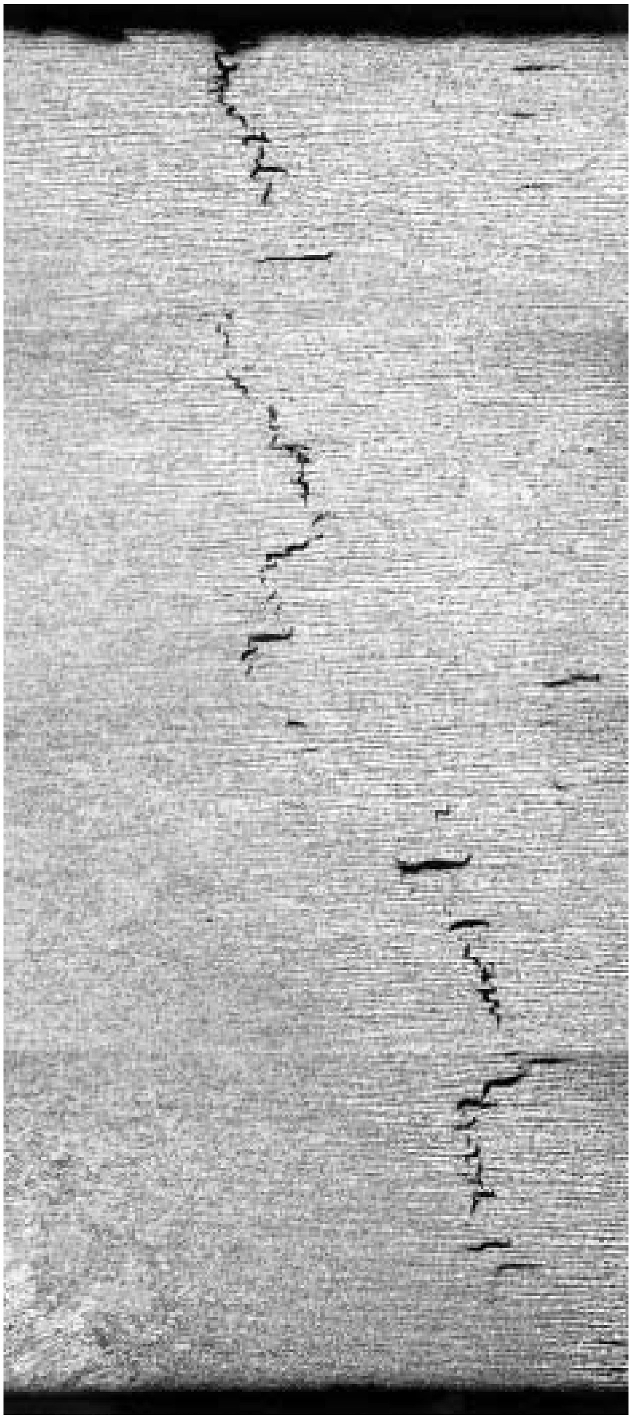

FIGURE 2—SOHIC in Carbon Steel Under Applied Stress. Direction of tensile stress is normal to cracks linking the blisters.